Parallel ray tracing algorithm for numerical analysis in radiative media physics

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Abstract. An original algorithm was developed for ray tracing across unstructured 3D grid. The resulting set of the rays provides the base for the grid-characteristic computation of radiative energy transfer in the high-temperature plasma simulations using MPI parallel technique and grid decomposition. The algorithm is implemented as a C++ code and incorporated in 3D magneto hydrodynamic (MHD) Eulerian code. Accurate rational calculations using integers of unlimited range are applied for the intersection of rays with grid elements. Tracing of different rays within a single MPI-process is carried out in parallel with the use of OpenMP threads. Acceleration and scalability of the implemented algorithms were investigated including a comparison with other solvers within MHD code. The developed algorithm provides accounting the anisotropy of the radiation field in complex multiscale 3D MHD simulations. Proposed applications are the following: 1) postprocessing the results of 3D simulations (numerical pinhole imaging, estimation of the radiation output in a given direction); 2) modeling the propagation of the laser radiation; 3) calculating the thermal radiation field on the basis of quasi-diffusion model (improvement of the Eddington factor for the diffusion approximation).

Keywords. Ray tracing, unstructured 3D grid, radiation transport, high-temperature plasma simulations, magneto hydrodynamics, MPI, OpenMP

1. Introduction

Radiative energy transfer is an important part of high-temperature gas-dynamic processes. The thermal radiation begins to affect the heat exchange significantly, when the gas temperature is about 10^4K. At very high temperatures, the radiation of the substance affects its dynamics as well. Such phenomena are, for example, processes in stellar atmospheres, space vehicle reentry, high-current discharge, laser plasma [1]. A problem of today is the development of powerful ultraviolet and soft X-ray sources for nanotechnology, controlled fusion, laboratory astrophysics and fundamental studies of the matter properties under extreme conditions. All these tasks require high-precision predictive modeling with taking into account real-life the geometry and materials. This type of computations involves coupled radiation gas dynamic (RGD) problems, as gas-dynamic parameters are influenced by radiative heat transfer, and thermal radiation field depends on the emissivity and opacity of the gas. High-resolution computation of

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